14. The adult colour-pattern of *Hippolyte cranchii* is constant, but develops indirectly. The adolescent possesses a special colour-pattern developed in large measure in relation with the primary system of the zoea. Both persist though concealed by the independently developed adult pattern.

15. In *Hippolyte varians*, several adult colour-patterns occur. They develop indirectly. The primary system is the same in all.

In the adolescent, three distinct colour-patterns arise:—"barred," "liner," and "monochrome."

These may persist, becoming barred, liner, or monochrome adults.

Or either "barred" or "liner" may, by developing superficial or deep chromatophores, become a monochrome.

Or, by localised superficial developments either "barred" or "liner" may give rise to a "blotched" adult colour-form, under which the adolescent pattern is hidden.

The primary system is inherited: the adolescent colour-patterns are possibly inherited; but inheritance is immaterial since the final goal is reached by any adolescent road; that is, the adult colour-pattern of *Hippolyte varians*, is the result of environment.

"Observations on 'Flicker' in Binocular Vision." By C. S. Sherrington, M.A., M.D., F.R.S. (Thompson-Yates Laboratory of Physiology, University College, Liverpool). Received July 30, 1902.

The connection between the physiological state and reactions of the two retinæ right and left is close in many respects; this is true particularly and peculiarly for their areas that are conjugate in binocular vision, that is, which receive corresponding images of objects perceived in the binocular field. The observations at basis of the following communication attempt to obtain further information regarding the nature of the tie between these retinal so-called "identical spots." A practical aim was to measure by the "flicker" method of photometry any difference of physiological luminosity existent between binocular and uniocular vision of a given illuminated object.

An object intermittently illuminated gives, if the frequency of intermission be sufficient, a perfectly steady sensation. The successive retino-cerebral reactions fuze into a continuous one as judged of by sensation. If the rapidity of intermission be less than the requisite, the sensation oscillates through lighter and darker phases. The transition from the oscillating to the steady sensation and *vice versâ* is sufficiently abrupt to form a transition point capable of fairly definite

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fixation in time. It has been used in this enquiry as an index for noting the influence of the physiological state of a spot in one retina upon that of the "identical" spot in the other retina. A second index taken has been the visual "brightness" of the perceived image.

For the observations desired, it was considered important that extinction and re-illumination of the image occur *pari passu* in the two eyes, *i.e.*, with like speed, along a like direction in the retinal surface, and at "identical spots." It seemed also important to maintain perceptual singleness of the object seen, thus placing the "identical spots" in the most favourable condition for their co-operative identity. For this reason a steady and considerable degree of "convergence" of the visual axes was made one condition of the observations. The degree of focal accommodation of the eyes was arranged to correspond with the amount of convergence. Variations in the aperture of the pupil were excluded by wearing small artificial pupils.

The illuminated object was arranged as follows. A small double sheet of thick "milk" glass was illuminated by a candle-shaped, single-loop, incandescent electric lamp, with frosted glass front. The lamp was fed at rather above its intended voltage by accumulators unused during the experiment for any other purpose than the lighting of the lamp. The lamp was set in the axis of a rotating cylinder. In this latter were openings of appropriate size, different according to the different requirements of the observation. The lamp was not fixed to the cylindrical screen. The milk glass was set close inside this screen. Outside the moving cylindrical screen was a fixed cylindrical screen concentric with the revolving one. In the fixed cylindrical screen four circular holes were arranged so that two were centred on the same horizontal line, and of the other two, one was centred as far above the left-hand hole of the previous pair as the second was below the right-hand member of the pair. These holes were viewed from a distance such that when the line of the visual direction of the left eye passed through the centre of the lower left hole it met at the axis of the cylindrical lantern, the line of visual direction of the right eye passing through the centre of the upper right-hand hole. A blackened vertical screen cut off from the left eye all view of the right-hand holes, and from the right eye all view of the left-hand holes. A pair of weak prisms with base-apex line vertical sufficed to bring the images of the right-hand and left-hand holes to the same levels. The images then immediately fused under convergence. Cross horizontal and vertical wires across the component holes served to certify binocular or monocular vision to the observer. When the four holes were all allowed to contribute images they were seen by the observer as two small evenly-lighted discs, one vertically above the other, with a delicate cross-line on each. Any one of the holes could be separately screened out of vision.

The spindle of the revolving cylindrical screen carried a step-pulley. From this a cord ran to a step-pulley fixed on the spindle of a small electromotor. The speed of running of this motor was controlled by a set of coil resistances, which formed a coarse adjustment, and by a fluid resistance in a trough 1 metre long, with a sliding electrode; this formed a fine adjustment. The speed of rotation of the cylindrical screen was recorded by marking the completion of each revolution of the spindle carrying the screen by an electro-magnetic signal writing on a travelling blackened surface. On the same surface the time was recorded by a writing clock marking fifths of seconds.

The observations required an operator to manage speed of motor, registration of time and revolutions, &c., and an observer who, seated in a dark compartment, gave his attention to the watching of the illuminated discs.

The shutters of the rotating cylindrical screen could be arranged so that the illumination of a retinal spot in one eye could be varied in time and intensity synchronously or asynchronously with that of the conjugate spot of the other eye. Of various combinations examined, the following may be cited as outlining the evidence obtained. The discs may be referred to as disc A and disc B.

Experiment 1.—When the disc A represents right retinal stimulation alone (*i.e.*, without left), the conjugate spot of the left eye remaining dark; and when the disc B represents right retinal stimulation with coincident synchronous (*i.e.*, of synchronous phase) intermittent stimulation of the conjugate spot of the left retina; the frequency, duration, and intensity of the light periods being alike at all the holes.

Then, steady sensation is obtained from disc A at frequencies of intermission lower than those required for giving steady sensation from disc B.

At speeds sufficient to give steady sensation at both discs, the disc B does not obviously differ in brightness from the disc A.

Experiment 2.—When disc A represents as before uniocular stimulation only,

And when disc B represents intermittent right retinal stimulation, together with a stimulation yielding steady sensation from the conjugate field of left retina.

And when the steady sensation from left retina corresponds with an intensity of light stimulus half that of the intermittent stimulus employed for the right eye, then the rate of intermission required for obtaining steady sensation from disc A is higher than that required for obtaining it from disc B.

At speeds sufficient to give steady sensation for both discs, the disc B does not obviously differ in brightness from the disc A.

Experiment 3.—The disc A representing uniocular vision as before.

When disc B represents intermittent right retinal stimulation with,

in same way as in 2, continuous steady sensation from the conjugate left retinal spot,

And when the intensity of that continuous sensation from left retina corresponds with an intensity of light stimulus more than half that of each stimulus employed in repetition for the conjugate of the right eye,

Then the rate of intermission required for obtaining steady sensation from disc A is higher than that required for obtaining it from the disc B.

Of the two discs, seen under speeds sufficient to give steady sensation from both, disc B appears the brighter.

Experiment 4.—The disc A representing uniocular vision as before.

When the disc B represents intermittent right retinal stimulation, together with, in the same way as in 2 and 3, steady sensation from the conjugate left retinal spot,

And when the intensity of that steady sensation from left retina corresponds with that due to a light stimulus of less than half the intensity of each member of the series of repeated stimuli employed for the conjugate spot of the right eye,

Then the rate of intermission required for obtaining steady sensation from disc A is higher than that required for obtaining it from the disc B.

And of the two discs, both seen under speeds sufficient to yield steady sensation, disc A appears the brighter, unless the field offered to the left eye is given by closing that eye or otherwise screening with a homogeneous darkness.

Experiment 5.—The disc A representing uniocular vision as before,

And when the disc B represents intermittent right retinal stimulation, the intervals of intermission exactly corresponding with periods of illumination of the conjugate spot of the left retina, and the intermittent stimuli being equal in intensity and duration for both right and left conjugate spots;

Then the rate of intermission required for obtaining steady sensation from disc A is higher than that required for obtaining it from disc B.

Of the two discs, both seen under speeds of intermission sufficient to yield steady sensation, the disc B appears to be of a brightness not obviously different from that of disc A.

Experiment 6.—With disc A as before.

When disc B represents intermittent right retinal stimulation, similar in every way to that applied to the conjugate of the left retina, except that its phases of light and shade precede or succeed those applied to the other retina by an interval of half a phase length,

Then the rate of intermission required for obtaining steady sensa-

tion from disc B does not appreciably differ from that required to obtain it from disc A.

Of the two discs, at speed sufficient to yield steady sensation, disc B does not obviousiy differ in brightness from disc A.

Experiment 7.—When disc A represents the binocular combination described for disk B, Experiment 1, and the disk B is as described in Experiment 6, the rate of intermission required to obtain steady sensation from A is higher than that required for obtaining it from B, but at speeds sufficient to yield steady sensation from both discs the two discs appear to be of equal brightness.

Experiment 8.—With disc A, as in Experiment 7, and disc B, as described in Experiment 6, the frequency of repetition of stimulus required to yield steady sensation from disc A is slightly higher than that required to obtain it from disc B, but at speeds sufficient to yield steady sensation from both discs the two discs appear of equal brightness.

Experiment 9.—With disc A, representing the binocular combination described for disc B in Experiment 5, and with disc B, as described in Experiment 6, the frequence of repetition of stimulus required to yield steady sensation at disc A is slightly lower than that required to yield it at disc B; but at speeds sufficient to yield steady sensation from both discs, the two discs appear of equal brightness.

The observations show (i) that Talbot's law, unimpeachable (over a wide range of ordinary luminosities) for the single eye, is not applicable to combined binocular vision, that is, that if the two eyes functioning together in binocular vision are considered as functionally to combine to a single organ, Talbot's law does not hold good for that organ as it does for the single eye, right or left. (ii) That increase of luminosity of an intermitting image does not always necessitate increase of rate of frequency to extinguish its flicker; and conversely, They also show that the "Fechner paradox" regarding binocular luminosity makes itself apparent under "flicker" examination as well as under "brightness" estimation.

It seems that the physiological sum of two luminosities perceived through conjugate retinal areas is of a value intermediate between the individual values of the two component luminosities.

Among experimental difficulties incident to the experiments may be mentioned the increased perception of flicker under paracentral as compared with central locus of stimulus on the retina, as noted by Exner and by Charpentier. Interesting experimental difficulties were also occasioned by the reciprocal and often antagonistic influences exerted by one retina upon another in ways studied and described recently by Dr. W. McDougall.*

It was further observed that binocular colour mixture did not seem

* 'Mind,' 1901.

to be either rendered easier or impeded when the components were applied by alternating right and left stimuli as compared with the method of applying them by coincident right and left stimuli.

"On the Influence of the Prolonged Action of the Temperature of Liquid Air on Micro-organisms, and on the Effect of Mechanical Trituration at the Temperature of Liquid Air on Photogenic Bacteria." By ALLAN MACFADYEN, M.D. Communicated by Professor JAMES DEWAR, F.R.S. Received August 2, 1902.

In previous communications it was shown that an exposure for twenty hours and for a period of seven days to the temperature of liquid air (about -190° C.) had no effect on the vitality of micro-organisms, whilst an exposure of ten hours to a temperature as low as that of liquid hydrogen (about -252° C.) was likewise without an appreciable effect.*

Further experiments have since been made in which the influence of the prolonged action of the temperature of liquid air on organisms was tested for a period of six months.

The bacteria employed were non-sporing forms, viz., *B. typhosus*, *B. coli communis*, and *Staphylococcus pyogenes aureus*, along with a Saccharomyces.

The bacteria were directly immersed in the liquid air, either on cotton-wool swabs enclosed in a perforated metal case, or on small loops of platinum wire. The yeast was washed and pressed, then wrapped up in rice paper, and directly exposed.

Samples were removed and tested at various intervals up to six months. In no case could any impairment of the vitality of the organisms be detected. The fresh growths obtained were normal in every respect, and the functional activities of the organisms were unaffected. The typhoid bacillus retained its pathogenic properties, and responded typically to the agglutination test; the colon bacillus exhibited its normal properties; the *Staphylococcus aureus* produced pigment on solid and an active hæmolysin in fluid media, whilst the yeast exhibited its fermentative power unimpaired.

The above experiments show that a prolonged exposure of six months to a temperature of about -190° C. has no appreciable effect on the vitality of micro-organisms. To judge by the results, there appeared no reason to doubt that the experiment might have been successfully prolonged for a still longer period.

*. 'Roy. Soc. Proc.,' February 1, 1900; *ibid.*, April 5, 1900; *ibid.*, May 31, 1900.